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EXPERIMENTAL WATERSHEDS USED AS A RESEARCH TOOL
BY THE FOREST SERVICE

by

Jack Rothacher

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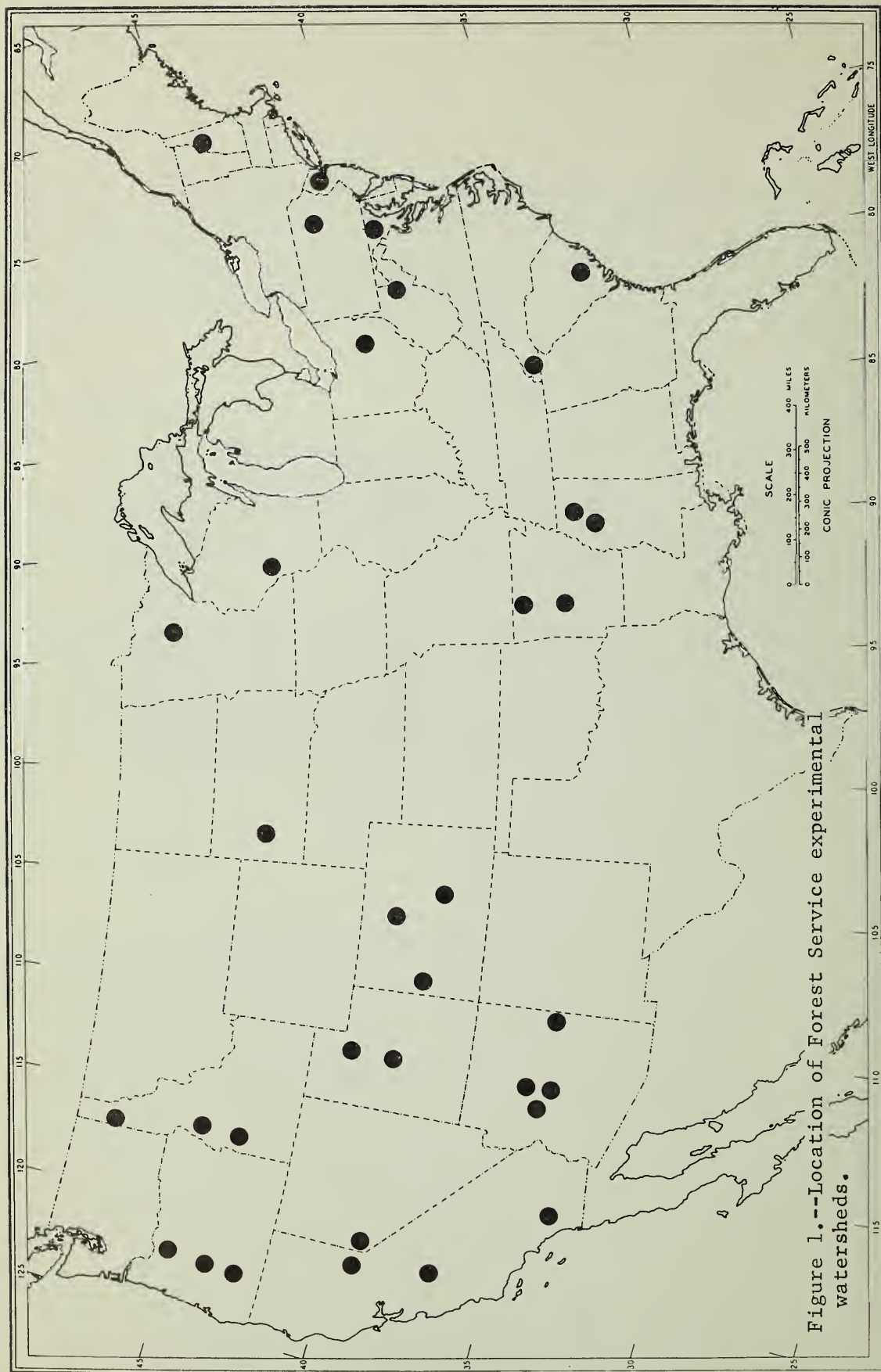


Figure 1.--Location of Forest Service experimental watersheds.

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Experimental watersheds are the traditional approach to study of the effect of land treatment on streamflow and sedimentation. In spite of emphasis on more basic research and the use of modern research techniques, watersheds still play an important part in the Forest Service's watershed management research program. A list of over 250 gaged watersheds is attached, and I suspect even this list is incomplete.

As can be inferred from figure 1, many of these watersheds are in the more mountainous headwater streams where forests remain the dominant vegetation. We recognize the importance of these lands for the production of water. In California, forested areas cover only 21 percent of the State yet yield 70 percent of the water. The 12 percent of the State within the forested snow zone is estimated to yield 50 percent of the water. Admittedly, yields from California forests may be above average, but all major rivers of the United States have headwaters in the forests, and more than half the water-flow of the country originates in such areas. We no longer claim that forests produce water but realize full well that forests are there because of the climatic factors--including higher precipitation. But we still maintain that how we manage the forests, and associated range and alpine areas, has an important effect on the characteristics of streamflow and quality of water produced.

Although specific objectives of Forest Service watershed studies cover a wide range, they all relate in some measure to the effect of various forest management practices on yield, distribution, or quality of water produced. In some areas, emphasis is on total yield, almost without regard for timing or quality; in other areas, flood flows and sedimentation may be most important; in still others, minimum flows of the year are of most concern; or, perhaps only quality is of prime importance.

On a portion of the experimental watersheds, snow plays a major part in the hydrologic regime. Some watersheds in the high Sierras, the Rocky Mountains, and in New England are devoted primarily to snowpack research. Snow studies in California have resulted in a comprehensive set of suggestions for managing forests in the snow zone. In Colorado, Wyoming, and Utah, effort is directed toward studies of the accumulation and melt of alpine snowfields. Research to induce drifting near snow fences has as an objective extension of the snowmelt period later into the summer when yields are most important.

Since forest lands must be managed for products other than water, the general objective of Forest Service watershed management research is to discover how to maintain an adequate flow of good quality water yet utilize the land for economic output of timber, grazing, and recreation.

Instrumentations on these watersheds differ. Gaging station designs are chosen to suit the area and study objectives. In recent years, there seems to be a preference for the 120° V-notch weir, which provides capacity without too much sacrifice of accuracy at low flows. Where sediment and debris are problems, flumes or flume and V-notch combinations are used. The H-flume has been used to handle light sediment loads and yet give reasonable accuracy at low flows.

Although most Forest Service stream gaging stations are installed and maintained by our own research personnel, in some areas this is done in cooperation with the United States Geological Survey or other agencies. Observations of precipitation, snowpack, and other climatic factors are handled in much the same way. Almost without exception, our men in the field have close working relations with other agencies making hydrologic measurement. I'm sure the exchange of information is mutually beneficial.

Watersheds maintained by the Forest Service range in size from less than half an acre to over 15,000 acres. Although the precipitation range is from a low of 12 to a high of 120 inches, the great majority of study areas receive 25 inches or more, well within the range usually associated with forest cover.

Results of watershed and associated studies are reported in a wide variety of publications. Short articles of timely interest are often published as a research note by the Forest Service Experiment Station at which the work was done. Longer manuscripts with more detailed information may appear as research papers. Many reports appear in the ever increasing number of professional journals. Although summary results of our studies are reported in readily available sources, we do not as yet have a procedure such as the Agricultural Research Service "Black Book" or United States Geological Survey "Water Supply Papers" for publication of basic data.

Some of our experimental watersheds date back to the 30's. Watersheds are expensive tools of research, and the question "Why more watersheds?" has been raised repeatedly; yet our listing shows a number of recent installations. Reinhart (1963) in his introduction to the now famous "Fernow Five," points out that "though we know the general nature of forest treatment effects on water, we have not learned nearly enough to prescribe a specific treatment to give a specific result. We do not yet understand how to manipulate vegetation to increase or reduce water flow by specific amounts. Though we are better able to recommend practical measures to reduce erosion and sedimentation, we lack detailed knowledge of the fundamental relationships between land treatment and water pollution." Perhaps the key to "Why more watersheds?" is the fact that we lack a really adequate substitute which will integrate all the complexities of climate, soil, and vegetation characterizing any given watershed.

Many of the earlier studies by the Forest Service are already familiar to hydrologists. With no attempt at completeness, I have listed some of our more recent findings below.

Water Yield

Most of our studies record some increase in annual streamflow with timber harvest. In the fifth year after commercial clearcutting on the Fernow Experimental Forest, the increased water yield was less than the first year (1.4 inches vs. 4.4 inches) but was still statistically significant.

This is the field in which we become involved in low rainfall areas and proposals to convert from higher water-using-vegetation to that making lower demands on the water supply. Results are sometimes not definite. A 22-acre watershed at the Coweeta Hydrologic Laboratory converted from hardwood to grass showed no increase in annual streamflow the first 3 years. But in the 1963-64 year, significant increases were noted in each of four 3-month periods. The increase was roughly paralleled by decreasing net production of dry matter by the grass stand. On the San Dimas Experimental Forest, increased water yield resulted from conversion of brush to grass if (1) soils were more than 3 feet deep, (2) grass was maintained weed free, and (3) there was more than enough rainfall to replace the soil-water deficit each year.

How vegetation is altered seems important. On the 248-acre North Fork of Workman Creek (Arizona), clearing 80 acres of moist-site forest and replacing it with grass gave a 55-percent increase in water yield. Removal of 45 percent of the basal area in the South Fork by individual tree, distributed over the entire watershed, gave no significant change.

Practical application of research results are being tried at Johnston, N. Y. Plagued by recurrent water shortages, the city will cut some of the heavily stocked stands in its 4- to 5-square-mile watershed as a temporary solution.

I should point out that increased water yield is complicated by several problems: the difficulty of maintaining vegetation as we want it and the sacrifice of quality for quantity.

Water Quality

With few exceptions, increased intensity of use has resulted in increased sediment.

In the Lake States and in the South, studies show the decrease in sediment as vegetation changes from cultivated crops to pasture to wild lands. Sediment yields can be predicted from land use which in turn is closely allied to soil and geologic conditions.

On the Fraser Experimental Forest, annual sedimentation can be predicted with reasonable accuracy from annual peak discharge. Indications here are that the primary erosional process is by channel erosion (streambank cutting and channel degradation).

In recent years, intensive management has included the use of pesticides for protecting or controlling the vegetative cover. DDT contamination of Coweeta Creek was negligible after precise helicopter application on insect infestations in upslope and ridge areas. Over 1,000 gallons of silvicide (2,4,5-T in oil) applied in one month on two 55-acre watersheds in West Virginia left no detectable contamination (by "sniff" test good to 0.5 p.p.m.). Even when 2,4,5-T was sprayed on streambank vegetation, only light contamination was detected immediately after spraying and after the first large storm, and then only within the treated reach--no contamination was found downstream.

Peak Flows (Storm Runoff)

The influence of forest land management on storm runoff ranges from one of extreme importance to almost none. The influence of the vegetative cover is primarily a function of precipitation and soils.

On one extreme, we have areas of high intensity precipitation and highly erosive soils where vegetation largely governs the proportion of surface flow. The importance of the forest soil in these areas is emphasized by early Coweeta watershed studies in which, although tree cover was completely removed, no increase in peak flow resulted as long as the forest soil remained unchanged.

At the other extreme are the forests of the Pacific Northwest. Here our major flood flows originate from extended periods of low intensity precipitation or precipitation plus snowmelt. During these storms, a large part of the detention and retention capacity of soil is filled and output of storm runoff becomes essentially a reflection of input of precipitation. Under these conditions forests apparently have no measurable influence on peak flows. The recent storms of Christmas 1964 resulted in no change in the peak flow relations of calibrated watersheds even though approximately 80 percent of the timber had been cut on one of the drainages.

Other areas lie somewhere in between. Commercial clearcutting on the Fernow Experimental Forest increased storm runoff, often by high percentages of expected flow. Volume increases ranged up to one-half area inch. Such increases were largely the result of decrease in field-moisture deficiency rather than changes in surface and subsurface flows.

Low Flows

In general, our watershed studies show an increase in late summer flow with the removal of vegetation. Probably the only exception to this would be the extreme condition in which vegetation removal resulted in such a severe change in infiltration capacity of the soil that a large part of the precipitation left the area as surface flow, reducing the subsurface flow that normally sustains summer streamflow.

Studies on the Fernow Experimental Forest show an increase in low summer flow roughly proportional to the increase in percent of forest cover removed. Recent results from our studies in the Pacific Northwest also show this proportional increase with removal of forest cover.

Economics

The economics of management of forests for water production has been considered in only a few cases. In the Fernow studies, the estimated cost of increasing yield of water (silvicide plus timber production lost) averaged about \$0.04 for each additional 1,000 gallons.

Techniques

Among our personnel are some who are always looking for better ways of carrying out their research. Among other innovations are fibreglassed-plywood, trapezoidal flumes and an inexpensive vinyl-lined weir for small watershed studies. Multivariate analysis of streamflow and sediment data promises to be a useful tool of the future. And radioactive isotopes are being used to characterize the hydrologic performance of mountain snowpacks.

Precipitation Studies

Precipitation measurements, basic to watershed studies, have received considerable attention in the past. But still we are evaluating rain gage networks and methods for determining average watershed precipitation.

In the mountains, snow fences have become a tool of watershed management. In Colorado 10-foot-tall snow fences increased maximum snow depth an average of 2 feet over a distance of 300 feet in mid-May in one area; 5 to 6 feet for a distance of 190 feet in another. Even in a poor snow year, an extra acre-foot of water was available for streamflow on July 1, 1963, for each 70 feet of fencing.

Recent analysis of snowmelt characteristics, in western white pine forests, indicates that the density of the forest canopy--hence by inference the effect of timber cutting--explains more snowmelt variance than any other factor.

This brief review of watershed and associated studies being conducted by the Forest Service gives some idea of their range, geographically, climatically, and by objective. Though watersheds are a crude tool, it looks like they will be valuable, for many years to come, in extending our inadequate knowledge of how to manipulate vegetation to obtain desired flow of water.

EXPERIMENTAL WATERSHEDS - U.S. FOREST SERVICE

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Location	Estab. Dates	Mean Precipi- tation	Forest Cover	Gaging Stations Type	No.	Acres	Remarks
<u>NORTHEAST</u>							
Hubbard Brook (W. Thornton, N.H.)	1955	40-50	N. hardwoods, spruce and fir	90°+120° V-notch, San Dimas + 90° V-notch	7	29-180	Effect of forest cover on water yield, rate of delivery, and quality.
Fernow (Parsons, W. Va.)	1948	58	Appalachian hardwoods	120° V-notch	7	38-96	do
Open Land (do)	1963	do	Old field	do	2	29-46	
Dilldown (Kingston, Pa.)	1948	55	Scrub oak	Columbus deep- notch	1	1,530	Coop.-Penn. Dept. Forest & Waters & USGS Effect of conversion from scrub oak to pine on water economy.
Baltimore Municipal (Baltimore, Md.)	1959	38	Oak-hickory	120° V-notch	3	22-38	Coop. City of Bellevue.
Newark Municipal (Newark, N.J.)	1959	45	do	do	3	24-68	Coop. City of Newark
Leading Ridge (State College, Pa.)	1958	39	Oak	90° V-notch in Trenton type weir	3	125-305	Coop. The Penn State University
Shale Hills (State College, Pa.)	1962	39	Oak	Various	3	20-125	Coop. The Penn State University

EXPERIMENTAL WATERSHEDS - U.S. FOREST SERVICE

Location	Estab. Dates	Mean Precipi- tation	Forest Cover	Gaging Stations Type	No.	Acres	Remarks
<u>SOUTHEAST</u>							
Coweeta Hydrologic Lab. (Franklin, N.C.)	1934	80	S. Appalachian hardwoods	90° V-notch	6	22-50	One in operation 1 year in three (Standby) Remainder in continuous operation
do		80	do	120° V-notch	12	31-212	Not currently in operation.
do		do	do	Rect.-crest 5'-6'	2	356-943	do
do		do	do	Cipolletti crest 12'	2	1788-1877	
Santee Expt. Forest (Charleston, S.C.)	1963	46	Coastal plain	AU-3 Natural control	1 1	400 8000	
<u>CENTRAL STATES</u>							
Dover, Ohio	1959	38	Oak-hickory	90° V-notch	2	18-23	
Eastern, Kentucky	1964		Disturbed strip mined areas outcrops	San Dimas flumes (1, 1-1/2, 2 ft.)	6	up to 60	
do	1964		Disturbed strip mined areas	Ponds	6	up to 5	
do	1964		Disturbed strip mined areas Terraces	San Dimas flumes (1, 1-1/2, 2 ft.)	6	2-5	

EXPERIMENTAL WATERSHEDS - U.S. FOREST SERVICE

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Location	Estab. Dates	Mean Precipitation	Forest Cover	Gaging Stations Type	No.	Acres	Remarks
<u>LAKE STATES</u>							
Marcell Expt. Forest (Grand Rapids, Minn.)	1960	25	Bog - Black spruce	12° V-notch H-flume	2	24	Bog and upland areas included.
do	1961	25	do	do	3	65-110	do
do	1963	25	do	do	1	20	do
Coulee Expt. Forest (LaCrosse, Wis.)	1960	32	Oak-hickory	90° V-notch	2		Spring-fed stream
do	1960			2-ft San Dimas	4	22-100	
do	1961			H-type trape- zoidal	30	2-20	
do	do			120° V-notch	1	53	
<u>SOUTH</u>							
Forest Hydrology Lab. (Oxford, Miss.)	1957	52	Abandoned fields	H-flume	3	2-3	Storm runoff and erosion control (Effect of burn- ing and conversion to pine).
do	1957	52	Oak-hickory (depleted)	do	3	2-3	do
do	1958	52	Pine plantations	do	3	2-4	Storm runoff and erosion control.
do	1959	52	Pine-hardwood	do	3	3-5	do

EXPERIMENTAL WATERSHEDS - U.S. FOREST SERVICE

Location	Estab. Dates	Mean Precipitation	Forest Cover	Gaging Stations Type	No.	Acres	Remarks
<u>SOUTH (cont.)</u>							
Forest Hydrology Lab. (Oxford, Miss.)	1964	52	Pine plantations	H-flumes	5	4-7	Storm runoff and erosion control (Effect of cutting methods)
Koen Expt. Forest (Harrison, Ark.)	1964			H-flumes	7	3-20	Effects of cover changes, water movement in soil.
Alum Creek Expt. Forest (Jessieville, Ark.)	1963			H-flumes (4.5')	1	32.5	Effect of management practices.
do	1961-2			H-flumes (3.0')	3	1.3-1.6	Effect of burning, cutting and T.S.I.
Coffeeville, Miss.				H-flumes	5		
<u>ROCKY MOUNTAIN</u>							
Fraser Expt. Forest St. Louis Creek (Fraser, Colo.)	1943	24	Spruce-fir, lodgepole	8' Cippolletti	1	1984	Effect of timber cutting on snow accumulation and water yield.
Fool Creek (Fraser, Colo.)	1940	24	do	Comb. broad-crested trapez. weir w/rect. flume	1	714	do
do	1955			120° V-notch	2	306 & 667	
Mingus Mb. (Prescott N.F., Ariz.)	1956	22	Chaparral	1 ft, 120° V-notch with San Dimas flume	3	46	Effect of chem. treatment chaparral on water yield and sedimentation.

EXPERIMENTAL WATERSHEDS - U.S. FOREST SERVICE

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Location	Estab. Dates	Mean Precipitation	Forest Cover	Gaging Stations Type	No.	Acres	Remarks
Whitespar (Prescott N.F., Ariz.)	1958-9		Chaparral	1-ft. 120° V-notch with San Dimas flume	2	241-325	Eff. of chem. treatment of chaparral on water yield and sedimentation.
Arizona	1963-4		Grassland	Weirs	2		High elev. 9,300 ft.
Castle Creek (Alpine, Ariz.)	1955	20	Mixed conifer	120° V-notch	2	1000	Eff. of commercial timber harvest on water yield and sedimentation.
Campbell Blue (Alpine, Ariz.)	1955	20	Pine	Villemonte Sill in concrete	1	7440	
Sage Brush (Dubois, Ariz.)	1958	20	Sagebrush	120° V-notch	3		Wooden cut-off walls
3-Bar (Roosevelt, Ariz.)	1956	25	Chaparral	90°+120° V-notch (concrete block)	4	50-274	Effect of wildfire and erosion control measures upon water, soil and game.
Natural Drainages (Sierra Ancha Expt. Forest, Ariz.)	1934	15	Chaparral	90° V-notch	4	9-20	Effect of grazing and chaparral conversion on water yield and sedi- mentation.
Parker & Pocket Creeks (Sierra Ancha Expt. Forest, Ariz.)	1932	15-25	Pinyon-juniper chaparral	Comb. Cipolletti and 90° V-notch	2	700-1000	Water yield from steep rugged watershed of shallow soil.

EXPERIMENTAL WATERSHEDS - U.S. FOREST SERVICE

Location	Estab. Dates	Mean Precipi- tation	Forest Cover	Gaging Stations		Acres	Remarks
				Type	No.		
Workman Creek (Sierra Ancha Expt. Forest, Ariz.)	1938	32	Pine-fir	V-notch trapez.	2	248-521	Effect of timber management types conversion on water yield and sedimentation
				flume. Comb.	1		
				Cipolletti and V-notch weirs	1		
Summit (Sierra Ancha Expt. Forest, Ariz.)	1928	17	Chaparral, desert		9	0.37-1.05	Recovery of deteriorated ranges and comparative sedimentation rates from shrubs and perennial grasses.
Wilton Creek (Apache N.F., Ariz.)	1958		Mixed conifer		2	343,570	Effect of timber harvest and removal on water yields and sedimentation.
Sturgis WS (Black Hills N.F., Rapid City, S.D.)	1963		Ponderosa pine		3	94-220	Pine mangt. and water yield and quality.
Black Mesa, (Grand Junction, Colo.)	1954	13-39	Pine-aspen	120° V-notch	3	100-400	
Beaver Creek (Prescott, Ariz.)	1956-7	20-30	Ponderosa pine	Modified trapezoidal	8	200-2000	Eff. of timber mangt. on water yield.
do		12-20	Pinyon-alligator juniper	do	3		Eff. of juniper removal on water yield and sedimentation.
New Mexico	1963		Pinyon-juniper	Fiberglass plywood flumes	6		Treatment effects on water yield and sedimentation.

EXPERIMENTAL WATERSHEDS - U.S. FOREST SERVICE

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Location	Estab. Dates	Mean Precipitation	Forest Cover	Gaging Stations Type	No.	Acres	Remarks
<u>INTERMOUNTAIN</u>							
Dog Creek (Reno, Nev.)	1959, 64	23	Jeffrey pine-Douglas-fir	Comb. broad-crested and 120° V-notch, one with Parshall flume	3	180-340	Winter rain-on-snow floods.
Davis Cty. (Farmington, Utah)	1930	21-50	Fir-aspen-mtn. brush	Mod. Venturi trapezoidal flumes	11	50-800	Erosion control
Centerville (Farmington, Utah)	1933	21-50	do	Self-cleaning flume 90°+120° V-notch	1	2025	
Parrish Cr. (Farmington, Utah)	1933, 57	21-50	do	120° V-notch	1	1378	
Great Basin Res. Center (Ephraim, Utah)	1941	33	Mountain meadow-fir	120° V-notch	2	375 & 220	
A & B (Ephraim, Utah)	1914	33	Mountain meadow	90°	2	10	
Tailholt Cr., Payette N.F., Idaho) & Circle End	1959-62	32	Ponderosa pine, Douglas-fir	O-Gee control section & 150° V-notch	1	1625 930	In coop. with Payette N.F. Granitic
Benton Cr. (Priest Riv. Expt. Forest, Idaho)	1938	42	White pine	Cipolletti weirs	2	950	
Silver Cr. (Boise N.F., Boise, Idaho)	1960, 64	32	Ponderosa pine	OG section - 2 Parshall flumes - 5	7	90-300	Water yield and quality

EXPERIMENTAL WATERSHEDS - U.S. FOREST SERVICE

Location	Estab. Dates	Mean Precipitation	Forest Cover	Gaging Stations Type	No.	Acres	Remarks
<u>PACIFIC NORTHWEST</u>							
H. J. Andrews Expt. Forest (Blue River, Oregon)	1952	94	Douglas-fir	Trapezoidal flumes	3	150-250	Effect of forest mangt. practices on streamflow and water quality.
			do	2-ft H-flumes	3	37-86	do
			do	Natural control	2	10,000-15,000	do
Bull Run (Portland, Oregon)	1956-7	120	Douglas-fir	Trapezoidal flumes	3	100-500	do
S. Umpqua Expt. Forest (Tiller, Oregon)	1960-3	34	Mixed conifer	120° V-notch, 3-ft	4	133-170	do
Entiat Watershed (Portland, Oregon)	1959	30	Ponderosa pine-fir	120° V-notch, 3-ft	3	1168-1393	do
<u>PACIFIC SOUTHWEST</u>							
San Dimas Expt. Forest (Glendora, Calif.)	1939		Chaparral	Comb. 90° V-notch weirs & 3 & 10-ft flumes.	17	35-8410	Intermittant operation after fire in 1960
	1960		do	Flumes	25	2-8	Erosion and peak flows
Teakettle Expt. Forest (Fresno, Calif.)	1956		Pine-fir	Comb. 90° V-notch and Cipolletti	4	70-550	Water yield from snowpack management
Onion Cr. Expt. Forest (Soda Springs, Calif.)	1957	74	do	120° V-notch weirs	5	120-560	do

EXPERIMENTAL WATERSHEDS - U.S. FOREST SERVICE

Location	Estab. Dates	Mean Precipi- tation	Forest Cover	Gaging Stations Type No.	Acres	Remarks
Caspar Creek near Fort Bragg, Calif. (on Jackson State Forest, Calif. Div. of Forestry)	1962	50	Douglas-fir- redwood (100-yr old second- growth)	120° V-notch in rectangular weir 2	1078-1264	Effect of logging and roads on water yield, sediment, and fish habitat.

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